HWS
Critical Design Review

Hobart and William Smith Colleges
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Mission Overview

Dimosthenis Chrysochoou, Misty Chien, Walden Marshall
Mission Overview

- Our payload has 3 subsystems:
  - Muon Detector
  - Magnetometer
  - Vibration damping

- Our subsystems are chosen with the purpose of acquiring additional data to aid in research.

The goal of our payload is to continue measuring different properties of the Earth (magnetic fields, muon flux at different altitudes). We also plan to study materials to dampen vibrations in order to open up new possibilities in the future for more sensitive equipment.

- We also plan to continue our outreach program the local middle school.
  - They will be taught some of the skills we have learned to promote youth interest in STEM.
A magnetic field is created by moving charges (current). It is a property of space that determines the magnetic force on an object. A charge, \( q \), with velocity, \( \vec{v} \), experiences a magnetic force \( \vec{F} = q\vec{V} \times \vec{B} \).
Theory and Concepts - Muons

- Muon is a subatomic particle with a charge of \(-e\) and mass about 200 times that of an electron, which are produced as cosmic rays collide with the Earth’s atmosphere.
- Because of atmospheric density, we expect to see a lower muon flux as altitude increases.

- Muon detector consists of plastic scintillator, silicon photomultiplier, and custom printed circuit board.
- Muons cause illumination of the scintillator, which is translated to a voltage signal and amplified by the silicon photomultiplier. This signal is shaped by the circuit board so that it can be read by the connected microcontroller. Muons produce higher amplitude signals than other particles.
Theory and Concepts – Vibration Damping

- Changing air density and rocket fuel combustion cause oscillating forces in the rocket.
- We can "damp" the magnitude of these oscillations using certain liquids.
- Measuring the forces, using an accelerometer, we can determine certain materials' natural frequencies.

![Diagram showing amplitude vs. driving frequency with three damping scenarios: small, medium, and heavy damping.](image-url)
Concept of Operations

Altitude

Decreasing $|B|$ and muon flux
$t \approx 1.3$ min
Altitude: 75 km

Apogee
Lowest $|B|$ and muon flux
$t \approx 2.8$ min
Altitude: $\approx 115$ km

End of Orion Burn
Decreasing $|B|$ and muon flux
$t \approx 0.6$ min
Altitude: 52 km

High Tumble Rate
$t \approx 4.0$ min
Altitude: 95 km

Increasing $|B|$ and muon flux
$t \approx 5.5$ min
Chute Deploys

$t = -3$ min
-Switch on
-All systems on
-Begin data collection

$t \approx 15$ min
Splash Down
Power Remains On
Expected Results

- Decrease in magnetic field magnitude with altitude

- Decrease in muon flux with altitude
Expected Results

- Various resonant frequencies and damping properties for different fluids

Control accelerometer
Vibration dampened accelerometer
Success Criteria

• Minimum Success Criteria: data is collected from each of our subsystems
• Comprehensive Success Criteria: data from subsystems is collected, and due to noise minimization, is interpretable
Functional & Design Requirements:

- **F.R.1**: System shall record magnetic field readings during the entirety of the flight.
  - D.R.1.1: System includes 3 axis magnetometer with a range including 45µT to 55µT.
  - D.R.1.2: Magnetometer has extremely high sensitivity.

- **F.R.2**: System shall record muon flux data during the entirety of the flight.
  - D.R.2.1: Muon detector will have an appropriate scintillator volume in order to collect an adequate number of muon hits, without being excessively bulky.
  - D.R.2.2: Muon detector will output data at a rate high enough to avoid missing potential muon hits.
  - D.R.2.3: Muon detector coincidence circuit will not significantly reduce "real" muon hits.

- **F.R.3**: System shall record data from all accelerometers during the entirety of the flight.
  - D.R.3.1: System includes accelerometer with G-force reading capabilities of up to 50G.
  - D.R.3.2: Accelerometer axis orientation has an axis perpendicular to cross section of rocket.
  - D.R.3.3: Pistons are completely impermeable.

- **F.R.4**: Payload shall meet design compliance requirements.
## Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Analysis</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.R.1.1/2 Range/Sensitivity of Magnetometer</td>
<td>Test</td>
<td>Take readings from known currents and bar magnets</td>
</tr>
<tr>
<td>D.R.2.3 Muon Coincidence Circuit</td>
<td>Test</td>
<td>Run muon detector coincidence circuit next to last year's single muon detector; make sure coincidence circuit counts are not significantly lower</td>
</tr>
<tr>
<td>D.R.3.3 Strength of Liquid Container</td>
<td>Test Inspection</td>
<td>Subject pistons to compressive, tensile, and shear stresses as well as high amplitude vibrations; inspect for cracks</td>
</tr>
<tr>
<td>F.R.4 Design Compliance Requirements</td>
<td>Inspection Analysis</td>
<td>Payload will be 6.65±0.1 lbs, with a center of mass within a ½ inch cube at centroid, less than or equal to 4.75&quot; tall and 9.3&quot; in diameter (scale, CAD)</td>
</tr>
</tbody>
</table>
System Overview

Dimosthenis Chrysochoou, Willow Munn-Oberg,
Walden Marshall
System Definitions

- **MAG**: Magnetometer; measures the x, y, and z components of the magnetic field
- **MUON**: Muon detector; measures muon flux
- **VIB**: Vibration dampening experiment; accelerometers suspended in different substances measure the acceleration in x, y, and z direction
Notes on CAD:
- Mounting plates connections and supports are not modeled
- Using 2 Arduino Nanos, not 4
Changes from PDR

• Changed size of VIB pistons and eliminated liquid reservoirs
• Added a second mounting plate
Port Design Elements

• Not using any ports.
System Level Block Diagram

Legend

- **Data/Control**
- **9 Volts**
PCBs / Breadboards

• **Total number of PCBs**: 18
  – **MAG**: 8 (4 each assembly)
    • Magnetometer, logic level converter, microSD shield, RedBoard
  – **MUON**: 6 (3 each detector)
    • Main PCB (to shape signal) with temperature sensor, microSD board, SiPM (to detect photon incident)
  – **VIB**: 2 (1 per piston)
    • Accelerometer
  – **Arduinos**: 2 (1 for MUON, 1 for VIB)
Early Activation/G-switch

• We don't need a G-switch.
• We are relying on Wallops to switch on power T-3 with one connection.
Muon Detector Code

- The muon detector code comes from the Cosmic Watch website, including how to run the detectors in coincidence.

```c
MYMAIN (A) {
  if (analogRead(0) > SIGNAL_THRESHOLD) {
    int adc = analogRead(0);
    if (MASTER == 1) { digitalWrite(6, HIGH);
      count++;
      keep_pulse = 1;
    }
    analogRead(A3);
  }
  if (SLAVE == 1) {
    if (digitalRead(6) == HIGH) {
      keep_pulse = 1;
      count++;
    }
    analogRead(A3);
  }
  if (MASTER == 1) {
    digitalWrite(6, LOW);
  }
  measurement_date = total_date_time;
  time_stamp = millis() - start_time;
  measurement_t1 = micros();
  temperature = (((analogRead(A3) + analogRead(A1) + analogRead(A2)) / 3 * (5000. / 1024)) - 500) / 10.1;
  if (MASTER == 1) {
    digitalWrite(6, LOW);
    analogWrite(3, LED_BRIGHTNESS);
    Serial.println((String)count + " + time_stamps + " + adc + " + get_sipm_voltage(adc) + " + measurement_date_time + " + temperature + " + temperature);
    myfile.println((String)count + " + time_stamps + " + adc + " + get_sipm_voltage(adc) + " + measurement_date_time + " + temperature + " + temperature);
    last_adc_value = adc;
  }
  if (SLAVE == 1) {
    if (keep_pulse == 1) {
      analogWrite(3, LED_BRIGHTNESS);
      Serial.println((String)count + " + time_stamps + " + adc + " + get_sipm_voltage(adc) + " + measurement_date_time + " + temperature + " + temperature);
      myfile.println((String)count + " + time_stamps + " + adc + " + get_sipm_voltage(adc) + " + measurement_date_time + " + temperature + " + temperature);
      last_adc_value = adc;
    }
    keep_pulse = 0;
    digitalWrite(3, LOW);
    while (analogRead(0) > RESET_THRESHOLD) { continue; }
  }
```
Magnetometer Code

```
#include <SparkFun_MAG3110.h>

MAG3110 mag = MAG3110(); //Instantiate MAG3110

void setup() {
    Serial.begin(9600);

    Wire.begin(); //setup I2C bus
    Wire.setClock(400000); // I2C fast mode, 400kHz

    mag.initialize(); //Initializes the mag sensor
    mag.start(); //Puts the sensor in active mode
}

void loop() {

    int x, y, z; //Only read data when it's ready
    if(mag.dataReady()) {
        mag.readMag(&x, &y, &z); //Read the data
        Serial.print("X: ");
        Serial.print(x);
        Serial.print(" , Y: ");
        Serial.print(y);
        Serial.print(" , Z: ");
        Serial.println(z);
        Serial.println("--------");
    }
}
```

Accelerometer Code

```c
#include "SparkFun_LIS331.h"
#include <Wire.h>

LIS331 xl;

void setup()
{
  // put your setup code here, to run once:
  pinMode(9, INPUT); // Interrupt pin input
  Wire.begin();
  xl.setAutoAddr(0x19); // This MUST be called before .begin() as
  xl.begin(true); // .begin() can communicate with the chip
  xl.begin(LIS331::GDR_125); // Selects the bus to be used and sets
  // the power up bit on the accelerometer.
  // Also resets all accelerometer
  // registers that are user writable.

  // This next section configures an interrupt. It will cause pin
  // INTL on the accelerometer to go high when the absolute value
  // of the reading on the X-axis exceeds a certain level for a
  // certain number of samples.
  xl.setGConfig(LIS331::INTL3, 2); // Select the source of the
  // signal which appears on pin INTL. In
  // this case, we want the corresponding
  // interrupt's status to appear.
  xl.setIntDuration(50, 1); // Number of samples a value must meet
  // the interrupt condition before an
  // interrupt signal is issued. At the
  // default rate of 30Hz, this is one sec.
  xl.setIntThreshold(2, 1); // Threshold for an interrupt. This is
  // not actual counts, but rather, actual
  // counts divided by 16.
  xl.enableInterrupt(LIS331::F_S4, LIS331::INTL3, LIS331::YPOS_ON_HIGH, 1, true); // Enable the interrupt. Parameters indicate
  // which axis to sample, when to trigger
  // (in this case, when the absolute mag
  // of the signal exceeds the threshold),
  // which interrupt source we're configuring,
  // and whether to enable (true) or disable
  // (false) the interrupt.

  Serial.begin(115200);
}

void loop()
{
  static long longTimer = 0;
  int x, y, z;
  if (millis() - longTimer > 1000)
  {
    longTimer = millis();
    xl.readAxis(x, y, z); // The readAxis() function transfers the
    // current axis readings into the three
    // parameter variables passed to it.
    Serial.print(x);
    Serial.print(y);
    Serial.print(z);
    Serial.print("x, y, z: ");
    Serial.print(x, 2);/* The convertToG() function
    Serial.print(x, convertToG(100, x)); /* accepts as parameters the
    Serial.print(y, convertToG(100, y)); // raw value and the current
    Serial.print(y, 2); // maximum g rating.
    if (digitalRead(9) == HIGH)
      Serial.print("Interrupt");
    Serial.println();
  }
```
System Software Flow Diagram

WFF

Load program
Turn on accelerometers
Read from accelerometer 1
Read from accelerometer 2
Write to SD card
Write to SD card

Load program
Turn on Muon detector
Collect data
Write to SD card

Load program
Turn on magnetometer
Collect data
Write to SD card
De-Scopes

• The scope of our project has remained the same. We have maintained the three subsystems.

• The scale of our VIB subsystem has been changed (3 large pistons to 2 small pistons).
Off-Ramps – MAG

• MAG: minimum amount of magnetometers.
  – Less money spent.
  – Less coding and building.

  – Less useful data.
Off-Ramp – MUON

• **MUON**: reduce scale to one detector.
  – Less time expended on manufacturing.
  – Removes need to apply coincidence coding to system.

  – Increases risk of noisy data
  – Less data gathered; potentially less useful data gathered.
  – Higher risk of malfunction of subsystem.
Off Ramp - VIB

- Use only one piston
  - Can only test one liquid, but minimizes cost, manufacturing/testing time, and risk of leak while maintaining single axis measurement

- Suspend coated accelerometer in fluid
  - Can test multiple liquids, but requires redesign, remanufacturing, retesting, and doesn't allow for single axis measurement
Special Requests

• Our payload placed far away from other payloads with high current
  – High current will interfere with the magnetometer's data collection
Subsystem Design
Magnetometer Subsystem

Dimosthenis Chrysochoou
Magnetometer Decisions

• Our goal is to measure the Earth's magnetic field with the highest possible precision and accuracy.

• A magnetometer should have high enough sensitivity, adequate range of measured values, and high data output rate.

• The MAG3110 Magnetometer has the following features
  • Full Scale Range $\pm 1000 \mu$T
  • Sensitivity of 0.10 $\mu$T
  • Maximum Data Output rate of 80 Hz
## MAG: Trade Studies

<table>
<thead>
<tr>
<th>Magnetometer</th>
<th>MAG3110</th>
<th>MLX90393</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Availability</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Range of measurements</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Output Data rate</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Average</td>
<td>8.6</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Magnetometers MAG3110 and MLX90393
MAG: Electrical Block Diagram

- Magnetometer
- Logic Level Converter
- RedBoard
- SD shield
- Power Supply 9.0V
- WFF t-3

Data:
- V+:
- Ground:

Voltages:
- 3.3V
- 5.0V

Logic Level Converter:
- 3.3V
- 3.3V
- 5.0V
MAG: Code Block Diagram

- Start
- Load program
- Collect data
- Store to SD card
Hardware Used

- SparkFun MAG3110 Triple Axis Magnetometer
- SparkFun RedBoard - Programmed with Arduino
- SparkFun Logic Level Converter
- SparkFun microSD Shield
- SanDisk Ultra - flash memory card - 16 GB - microSDHC UHS-I
- Break Away Headers - Straight
- Jumper Wires

- All of the above items have been purchased
Hardware Used: Magnetometer

Top-view

Bottom-view
Hardware Used: RedBoard

Top-view

Bottom-View
Hardware Used: Logic Level Converter

Top-View

Bottom-View
Hardware Used: MicroSD shield
Hardware Used: Jumper Wires and Headers
Magnetometer CAD

- Magnetometer
- Logic Level Converter
- MicroSD shield
- RedBoard

Dimensions:
- Height: 23.00mm
- Width: 54.00mm
- Depth: 70.00mm
MAG: Risks

• The horizontal represents the likelihood of a risk, the vertical is the corresponding consequence.
• Risks placement should help drive mitigation priority

MAG.RSK.1: The subsystem doesn’t collect any data due to failure of the electronic components (Magnetometer, Arduino, SD card, Power Supply etc.)

MAG.RSK.2: The collected data are not useful due to strong magnetic interference.
MAG: Risks

- MAG.RSK.1: A backup system will significantly reduce the probability of failure of the electronic components. One option would be to use 2 Magnetometers, 2 Arduinos and 2 SD cards. In the case, of successful operation of these components we can also check the consistency of our data.

- MAG.RSK.2: Strong magnetic interference can be generated from other experiments on the rocket. Experiments that involve large electric currents will result in large magnetic fields.
Final Design

- The design of the MAG3110 Magnetometer is **complete in terms of hardware**. The parts that will be used include the magnetometer, the logic level converter, the ReadBoard, the microSD shield, and a 9V Alkaline battery.

- The design of the MAG3110 is **incomplete in terms of software**. Currently, our team is able to record data from the magnetometer and read it through the Arduino Serial Monitor and Serial Plotter. The next step is to develop the necessary code in order to save the data to the SD card.

- Lastly, our team is considering **adding one more magnetometer** in the subsystem. In the trade studies presented earlier we observe that the scores of the MAG3110 and MLX90393 are significantly close (8.6—8.4=0.2). The addition of another magnetometer will provide additional useful data.
Muon Detector Subsystem

Misty Chien
MUON: Materials

- Cosmic Watch PCB, Arduino nano, SiPM, SD card, Plastic Scintillator
MUON: Design

• Two plastic scintillators with coincidence circuit to improve the accuracy of our data along the axis
  – To reduce radiation: we will use lead shielding (high molecular density) between scintillators
  – To reduce background/noise: we will use coincidence measurement to lower the probability of detecting noise pulse
  – Plastic scintillators are known to show light output saturation when the energy density is large (Birks’ Law) \( \frac{dL}{dx} = S \frac{dE}{dx} \frac{1}{1 + k_B \frac{dE}{dx}} \).
  – We will be adding a temperature sensor chip right onto the main PCB
MUON: Design

- Having two scintillator plates, along with lead shielding + coincidence measurement should help with accuracy.
MUON: Design

3D-printed container

~41 mm
~6.35 mm
~41 mm
MUON: Electrical Block Diagram

MUON

Arduino

SD card

Power 9.0V Alkaline

WFF t-3

Data: ➔
V+: ➔
Ground: ➔

MUON: Arduino

Data: ➔
V+: ➔
Ground: ➔

SD card

WFF t-3
MUON: Code Block Diagram

1. Start
2. Load program
3. Collect data
4. Store to SD card

Flow diagram: Start → Load program → Collect data → Store to SD card
MUON: Trade Studies

• Microcontroller: Arduino Nano, Uno, mega
  ○ We decided with Arduino Nano due to space constraints

• Types of muon detectors:
  ○ We decided to use the plastic scintillator detector because of pulse detection, works best with Cosmic watch components
MUON: Risk Matrix

- The horizontal represents the likelihood of a risk, the vertical is the corresponding consequence.
- Risks placement should help drive mitigation priority

- **MUON.RSK.1**: System not powered on
- **MUON.RSK.2**: Microcontroller/SD fails in-flight
- **MUON.RSK.3**: The system can’t survive launch conditions
- **MUON.RSK.4**: No temperature data is collected if the temperature sensor fails to activate
MUON: Risks

- **MUON.RSK.1** (power-on) can be mitigated by careful soldering connections and testing the software. It has not moved down in *possibility* as we have yet to make any software tests.

- **MUON.RSK.2** (microcontroller/SD card fail) can be mitigated with prior testing and a backup system. The SD cards are positioned such that they won’t fly out from the centripetal acceleration of the payload.

- **MUON.RSK.3** (survive launch conditions) has been moved down in *possibility*, as there are no decisions made to use materials/structures that are high-risk.

- **MUON.RSK.4** (temperature sensor fail) has been lowered in *consequence*, as the temperature data does not affect our muon flux data.
MUON: Status

• The hardware design of our muon detector subsystem is considered FINAL. We are in the process of acquiring the plastic scintillators and other electrical components to assemble the detector to be ready for testing.

• The software design of our muon detector is INCOMPLETE. We have yet to test any software.
Vibration Damping Subsystem

*Walden Marshall*
VIB: Materials

- Hexamethyldisiloxane (low viscosity)
  
  [Link](http://www.clearcoproducts.com/pdf/damping-fluids/sds/SDS-PSF-0.65cSt-Silicone-Damping-Fluid.pdf)

- PSF-12,500cSt Silicone Damping Fluid (high viscosity)
  
  [Link](http://www.clearcoproducts.com/pdf/damping-fluids/sds/SDS-PSF-12,500cSt-Silicone-Damping-Fluid.pdf)
VIB: Materials

- Airpot Dashpot
VIB: Decisions for Design

• In order to achieve significant damping, we must maximize liquid compression

• In order to maximize compression, we must maximize stress (force per area), meaning
  – Have a large mass attached to the piston
  – Have a small area that the force is acting on
VIB: Decisions for Design

Strain vs Stress for 0.65 cSt and 12,500 cSt silicone oils

0.65 cSt hexamethyldisiloxane
12,500 cSt silicone oil

VIB: Decisions for Design

- The black lines indicate the stress on the liquid at certain accelerations if we attach a one pound weight to a piston with radius 0.11"
- We expect to see measurable (1%) liquid compression starting at about 10G, and up to 3% compression at maximum acceleration
VIB: Decisions for Design

- Shear modulus of stainless steel: 11.2E+6 PSI
- Rod experiences shear forces of 1 lb * 10G
- In order to not bend, rod must have cross sectional area of at least 8.93E-7 sq. in., meaning at least 5.33E-4 in. radius, which will easily fit inside the 0.11" glass cylinder
The graphite piston will be placed far up the cylinder as shown for two reasons:

1. It allows for a short rod connecting the graphite piston to the 1 pound mass, which will minimize torque about the junction
   - Torque radius to the center of mass of the weight is 0.6", so the joint must be able to withstand 1/2 ft. lb. (0.68 N m) of torque
2. It allows for a large volume of liquid to be placed in the cylinder, so the small changes in volume will result in a larger magnitude of motion, and more easily measurable damping
   - This design allows for 0.2" of movement, meaning about 9% volume reduction
   - We only expect to see up to 4% volume reduction at the maximum 25G, so this should be very safe
VIB: Electrical Block Diagram

Accelerometer → Arduino
Accelerometer → Arduino
Accelerometer → Arduino
Arduino → Data: V+:
Arduino → Ground:
Arduino → SD card

Power Supply 9.0V
WFF t-3
VIB: Code Block Diagram

Load program

Turn on accelerometers

Read from accelerometer 1
Write to SD card

Read from accelerometer 2
Write to SD card
## VIB: Trade Study

<table>
<thead>
<tr>
<th></th>
<th>LIS331</th>
<th>H3LIS331DL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Range of acceleration</strong></td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td><strong>Current</strong></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>
VIB: Other

Hardware

Power:
• 300 µA * 9V * 3 accelerometers = 0.081 W
• 50 mA * 9V * 1 arduino = 0.45 W

Total: 0.531 W

Weight:
• 2 * 1 lb weight = 2 lb
• 0.12 in³/piston * ~1 g/mL * 2 pistons = 0.01 lb
• ~0.1 lbs/piston * 2 pistons = 0.2 lbs
• ~0.02 lb arduino nano

Total = 2.23 lb
VIB: Risks

- **VIB.RSK.1**: No data is collected (SD card falls out, bad soldering connection)
- **VIB.RSK.2**: The data is mostly noise (the accelerometer doesn’t maintain orientation for single axis measurement, or the liquid strain is too small for significant damping to be measured)
- **VIB.RSK.3**: The subsystem malfunctions and causes other subsystems to malfunction as well (liquids leak, 1 pound weight breaks off)

<table>
<thead>
<tr>
<th>Possibility</th>
<th>VIB.RSK.3</th>
<th>VIB.RSK.1</th>
<th>VIB.RSK.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
VIB: Risks

• VIB.RSK.2 (noisy data) has been moved down in consequence because even if the liquids' response time to the oscillating stresses is too slow, we can measure the static strain/stress behavior of the liquids while the rocket is accelerating upwards.

• VIB.RSK.3 (other subsystems malfunction) has been moved down in possibility because there is such a small volume of liquid being used that even if the dashpots leak, it is not as likely that the liquid will destroy other components.
VIB: Risk Mitigation

- **VIB.RSK.1**
  - Take extra care in soldering
  - Make sure wires have enough slack to avoid being pulled when the 1 pound weight moves

- **VIB.RSK.2**
  - Test accelerometers to make sure they operate well in single axis measurement

- **VIB.RSK.3**
  - Make sure fluid containers don't leak and can withstand large forces
  - Make sure steel rod can withstand up to 10 lbs * 1G shear force and 0.42 ft. lb. of torque
VIB: Risk Mitigation

• After dashpot has been filled with liquid, ends will be sealed, to add protection from leaking
• Very low volume of liquid in pistons
VIB: Backup Plan

Possible problem: the ~2% volume decrease is not large enough to give us measurable damping

Potential solution: connected reservoirs to increase liquid volume, and therefore increased piston displacement (similar to mercury thermometer)

Drawbacks: increased risk of leakage, more weight, more space on payload
VIB: Status

• Mechanical design of vibration damping subsystem is FINAL, but if something else changes that allows for more space/weight, I may try to draft a better version of the reservoir design.

• Software for the vibration damping subsystem is INCOMPLETE. No software has been tested.
Power and Weight Budgets

Walden Marshall
Subsystem Design – Weight Budget

• Present your subsystem weight and total weight similar to what is given at the right

• Full payload spaces MUST be AT 20±0.2 lbs
  – Shared partners must collaborate to meet this weight including the canister

• Canisters weight about 6.7 lbs

• \( \frac{(20-6.7)}{2} \)

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total Mass (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUON</td>
<td>1.906</td>
</tr>
<tr>
<td>MAG</td>
<td>0.118</td>
</tr>
<tr>
<td>VIB</td>
<td>2.23</td>
</tr>
<tr>
<td>Batteries</td>
<td>0.2</td>
</tr>
<tr>
<td>Mounting Plates (2)</td>
<td>1.5</td>
</tr>
<tr>
<td>Canister</td>
<td>6.7</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12.874</td>
</tr>
<tr>
<td>Over/Under</td>
<td>7.126</td>
</tr>
</tbody>
</table>
## Subsystem Design – Detailed Power Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Max Current (A)</th>
<th>Time On (min)</th>
<th>Watts</th>
<th>Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUON</td>
<td>9.0</td>
<td>0.60</td>
<td>18</td>
<td>5.40</td>
<td>0.18</td>
</tr>
<tr>
<td>MAG</td>
<td>9.0</td>
<td>0.075</td>
<td>18</td>
<td>0.68</td>
<td>0.0225</td>
</tr>
<tr>
<td>VIB</td>
<td>9.0</td>
<td>0.075</td>
<td>18</td>
<td>0.68</td>
<td>0.0225</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>0.75</strong></td>
<td></td>
<td><strong>6.75</strong></td>
<td><strong>0.23</strong></td>
</tr>
<tr>
<td><strong>Total Power Capacity</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>1.32</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Over (+)/Under (-)</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>1.10</strong></td>
<td><strong># of Flights Margin</strong></td>
</tr>
</tbody>
</table>
Prototyping/Analysis

Dimosthenis Chrysochoou, Misty Chien, Walden Marshall
Analysis Results/Planning

• Calculated VIB pistons dimension and stress capacity
  – Largest contributor to system weight
• Symmetry in payload design
• Most distance between magnetometer(s) and batteries
Prototyping Results since PDR

- Design for complete payload design (CAD)
- Designs for each subsystem (CAD)
- Populate Cosmic Watch PCB from last year's leftover parts
- Create magnetometer assembly
Prototyping Results: Magnetometer

On this first assembly of the magnetometer our team did the following:

- Soldered headers on each of the elements
- Connected the elements through the breadboard using jumper wires
- Powered the ReadBoard through a USB cable connected to a laptop
- Loaded the Arduino code through the USB cable
- Read (qualitative) data through the arduino serial plotter and monitor
Prototyping Results: Magnetometer

Data for a Constant Magnetic Field. The data are read from the Arduino serial monitor (left) and serial plotter (right).
This data is produced by varying periodically the distance between a bar magnet and the magnetometer.
Prototyping Results: Magnetometer

Rotation around x-axis

Rotation around y-axis

Rotation around z-axis
There are still parts we need to procure to complete the Cosmic Watch PCB before we can test it.

- We’ve soldered the SD and SiPM boards.
- We anticipate another one or two revisions of the electronics.
Manufacturing Plan

*Dimosthenis Chrysochoou*
### Agenda Item

<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procure sample pistons</td>
<td>Done</td>
</tr>
<tr>
<td>Procure smaller dashpots from Airpot with desired modifications</td>
<td>January 20</td>
</tr>
<tr>
<td>Procure silicon oil</td>
<td>January 27</td>
</tr>
</tbody>
</table>
Electrical Elements: Muon

- Cosmic watch components (PCB, SiPM, SD) need to be soldered

<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice soldering on old parts</td>
<td>Done</td>
</tr>
<tr>
<td>Acquire all parts needed for soldering PCB</td>
<td>January 27</td>
</tr>
<tr>
<td>Solder on final board &amp; make sure it is working</td>
<td>February 3</td>
</tr>
</tbody>
</table>
**Electrical Elements : Magnetometer**

<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice soldering on old parts</td>
<td>Done</td>
</tr>
<tr>
<td>Subsystem circuit on Breadboard powered through USB cable</td>
<td>Done</td>
</tr>
<tr>
<td>Include microSD shield on the subsystem, use direct connections between elements, power through 9V Battery</td>
<td>February 3</td>
</tr>
</tbody>
</table>
## Electrical Elements: Accelerometer

<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice soldering on old parts</td>
<td>December 5</td>
</tr>
<tr>
<td>Complete soldering for one accelerometer and Arduino</td>
<td>December 16</td>
</tr>
<tr>
<td>Have code complete so that accelerometer writes to SD card</td>
<td>January 20</td>
</tr>
</tbody>
</table>
System Software Flow Diagram

1. Load program
   - Turn on accelerometers
     - Read from accelerometer 1
       - Write to SD card
     - Read from accelerometer 2
       - Write to SD card
   - Load program
     - Turn on Muon detector
       - Collect data
       - Write to SD card
2. Load program
   - Turn on magnetometer
     - Collect data
     - Write to SD card
Software Elements

Our code will primarily be taken from existing Arduino libraries. Certain parameters will be modified later to optimize performance.

<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have accelerometer code ready for completely assembled subsystem</td>
<td>February 3</td>
</tr>
<tr>
<td>Have magnetometer code ready for completely assembled subsystem</td>
<td>February 3</td>
</tr>
<tr>
<td>Have muon detector code ready for completely assembled subsystem</td>
<td>February 3</td>
</tr>
</tbody>
</table>
Testing Plan

Walden Marshall
Mechanical Testing: Surviving Flight Conditions

- Vibration testing: paint shaker
- Temperature testing: oven, dry ice

For the muon detector and magnetometer, we can collect data at a certain point before and after the vibration or temperature exposure, and verify that our subsystems still collect data, and the data is the same.

For the accelerometers, we will have to create a vibration source of known frequency and amplitude, and measure it with vibration damping subsystem before and after temperature and vibration exposure.
Electrical/Software Testing: Muon Detector

Verify that coincidence circuit eliminates noise

Compare total muon hits of the coincidence circuit to muon hits of single detector, and see whether the coincidence circuit finds less. Also, compare to more sophisticated muon detector used by HWS Advanced Physics Lab.

Compare coincidence circuit to single muon detector when a sample of radioactive Cobalt 60 or Uranium ore is near, and make sure coincidence is not triggered by radiation.
Electrical/Software Testing: Magnetometer

- Verify that magnetic field measurements agree with calculated magnetic field for a specified current and distance from wire
- Verify that magnitude of the magnetic field vector is invariant of orientation of magnetometer
Electrical/Software Testing: Vibration Damping

- Measure known accelerations using accelerometers, verify consistency between theoretical and experimental measurements
  - Constant acceleration from allowing an object to slide down a frictionless track
  - Oscillating accelerations from a known mass on a spring with known $k$

\[ \omega = \sqrt{\frac{k}{m}} \]

Hooke’s Law:

\[ F_{spring} = -kx \]
User Guide Compliance

Willow Munn-Oberg
## Requirement | Status/Reason (if needed)
--- | ---
Center of gravity in 1" mid-can? | No analysis on center of mass, but elements were placed strategically to roughly balance mass; weighted standoffs help
Contained in can | 3.87" tall, 9.25" in diameter
Connected to can by 4/5 bulkheads on top and bottom only | 4 bulkheads at top and bottom
Mass of our payload 6.65 ± 0.2 lbs | 5.954 lb.; plan on using weighted lead standoffs
Shared canister clearance | Will not interfere, ½” separation between payloads
No voltage on the can | Need to construct payload first before this can be tested
Activation wires at least 4 ft | 6 ft
Activation wire at least 24 gauge, Teflon coated | 22 gauge
Early Activation: current < 1 A | Current shall not exceed 0.75 A
T-0 Activation: current < .1 A | Not using
Battery Type | Alkaline batteries
Project Management Plan
Willow Munn-Oberg
Organizational Chart

Faculty Advisor
Dr. Peter Spacher

Faculty Advisor
Dr. Ileana Dumitriu

Student Researchers

- Magnetometer
  - Dimosthenis Chrysochoou

- Vibration Damping
  - Walden Marshall

- Muon Detector
  - Misty Chien
  - Willow Munn-Oberg
## Schedule - Spring Term

<table>
<thead>
<tr>
<th>Date</th>
<th>Goal</th>
<th>Description</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPRING</td>
<td>TERM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/27/20</td>
<td>Acquire Parts</td>
<td>SiPM, scintillator, dashpots, silicone oils</td>
<td></td>
</tr>
<tr>
<td>1/21/20</td>
<td>Progress Update 1 pres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/3/20</td>
<td>Ready for Testing</td>
<td>completely assembled subsystems and functional code</td>
<td></td>
</tr>
<tr>
<td>2/11/20</td>
<td>Subsystem Testing Review pres.</td>
<td></td>
<td>Test subsystems</td>
</tr>
<tr>
<td>3/3/20</td>
<td>Progress Update 2 pres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/9/20</td>
<td>Have Full Payload Assembled</td>
<td>attach all subsystems, microcontrollers, batteries to mounting plates</td>
<td></td>
</tr>
<tr>
<td>3/13/20</td>
<td>Have Full Payload Tested</td>
<td></td>
<td>paint shaker, oven, dry ice</td>
</tr>
<tr>
<td>3/24/20</td>
<td>Integrated Subsystem pres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/14/20</td>
<td>Progress Update 3 pres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/19/20</td>
<td>Progress Update 4 pres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/27/20</td>
<td>Possible Program pres.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/1/20</td>
<td>Submit Launch Readiness doc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/10/20</td>
<td>Travel to Wallops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/18/20</td>
<td>Launch day!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POST</td>
<td>LAUNCH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/10/20</td>
<td>Submit launch results</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/24/20</td>
<td>Submit Final Report</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Budget (Monetary)

<table>
<thead>
<tr>
<th>Item/Event</th>
<th>Description</th>
<th>Source</th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half Canister Space</td>
<td>Payment to NASA for securing a space in the rocket</td>
<td>NASA</td>
<td>$6,000.00</td>
<td>1</td>
<td>$6,000.00</td>
</tr>
<tr>
<td>Canister Reservation</td>
<td>Payment to NASA to reserve a space in the rocket</td>
<td>NASA</td>
<td>$1,000.00</td>
<td>1</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Muon Electrical components</td>
<td>Any components needed to build the muon detector</td>
<td>Digi-Key</td>
<td>$100.00</td>
<td>N/A</td>
<td>$100.00</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>The sensor for detecting the Earth's magnetic strength</td>
<td>Digi-Key</td>
<td>$14.95</td>
<td>2</td>
<td>$29.90</td>
</tr>
<tr>
<td>Logic level converter</td>
<td>For converting 5V arduino logic to 3.3V IC logic</td>
<td>Digi-Key</td>
<td>$2.95</td>
<td>5</td>
<td>$14.75</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>Used for detecting vibrations</td>
<td>Digi-Key</td>
<td>$9.95</td>
<td>6</td>
<td>$59.70</td>
</tr>
<tr>
<td>Arduino</td>
<td>The microcontrollers that will drive the experiments</td>
<td>Digi-Key</td>
<td>$23.38</td>
<td>6</td>
<td>$140.28</td>
</tr>
<tr>
<td>Adafruit DataLogger shield</td>
<td>The MC will use this to store data</td>
<td>Digi-Key</td>
<td>$13.95</td>
<td>6</td>
<td>$83.70</td>
</tr>
<tr>
<td>Plastic Mounting plate</td>
<td>All of the experiments will be mounted to this plate.</td>
<td></td>
<td>$100.00</td>
<td>1</td>
<td>$100.00</td>
</tr>
<tr>
<td>3D Printing Filament</td>
<td>The mounts for the experiments will be printed</td>
<td></td>
<td>$60.00</td>
<td>N/A</td>
<td>$60.00</td>
</tr>
<tr>
<td>Travel</td>
<td></td>
<td></td>
<td>$0.00</td>
<td></td>
<td>$0.00</td>
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<tr>
<td>Hotels</td>
<td>Refugee Inn</td>
<td>$170.00</td>
<td>2</td>
<td>$4,000.00</td>
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<tr>
<td>Van</td>
<td></td>
<td>$800.00</td>
<td>1</td>
<td>$800.00</td>
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<tr>
<td>Gas</td>
<td>HWS to WFF</td>
<td>$0.70</td>
<td>1800</td>
<td>$1,260.00</td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
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<td>$15,161.88</td>
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<td></td>
<td></td>
<td>$16,678.07</td>
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</tr>
</tbody>
</table>
Funding

$6,252 obtained from club budget allocations.

Plans for acquiring further funding:
- Speak with Colleges President
- Individual fundraising
# Team Contact Matrix

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ileana Dumitriu</td>
<td>Faculty Advisor</td>
<td><a href="mailto:dumitriu@hws.edu">dumitriu@hws.edu</a></td>
</tr>
<tr>
<td>Peter Spacher</td>
<td>Faculty Advisor</td>
<td><a href="mailto:spacher@hws.edu">spacher@hws.edu</a></td>
</tr>
<tr>
<td>Misty Chien</td>
<td>Student Researcher</td>
<td><a href="mailto:misty.chien@hws.edu">misty.chien@hws.edu</a></td>
</tr>
<tr>
<td>Willow Munn-Oberg</td>
<td>Student Researcher</td>
<td><a href="mailto:willow.munn-oberg@hws.edu">willow.munn-oberg@hws.edu</a></td>
</tr>
<tr>
<td>Dimosthenis Chrysochoou</td>
<td>Student Researcher</td>
<td><a href="mailto:dimosthenis.chrysochoou@hws.edu">dimosthenis.chrysochoou@hws.edu</a></td>
</tr>
<tr>
<td>Walden Marshall</td>
<td>Student Researcher</td>
<td><a href="mailto:walden.marshall@hws.edu">walden.marshall@hws.edu</a></td>
</tr>
</tbody>
</table>
### HOBART AND WILLIAM SMITH COLLEGES:

Spring 2020 RS-C Team Availability Matrix

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 AM</td>
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<tr>
<td>8:00 AM</td>
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<td>9:00 AM</td>
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<td>11:00 AM</td>
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<tr>
<td>12:00 PM</td>
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</tr>
<tr>
<td>1:00 PM</td>
<td>No</td>
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<td>No</td>
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<tr>
<td>2:00 PM</td>
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<tr>
<td>3:00 PM</td>
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<td>No</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>No</td>
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</tr>
<tr>
<td>5:00 PM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**PLEASE USE MOUNTAIN TIME ZONE TIMES**

**PLEASE USE MOUNTAIN TIME ZONE TIMES**
Outreach

• We teleconferenced a 7th grade class at a charter school in Southern California. We discussed our careers as student scientists and answered their questions.
Project Summary

• We have no major remaining issues.
• Area of concern:
  – We are worried that our experiments are repetitive. This year, we have been working on improvements, rather than new experiments.
  – However, now that our members are much more acquainted with the RockSat program, we are excited about new experiments we could design in the future.
Worries

- Major worries or potential failure points:
  - paired with group with high current
  - In terms of design, we still need to work on structurally securing the two mounting plates
Conclusion

Our biggest priorities right now are getting everything we can soldered together, given the parts we have, and getting software up and running so we can perform more preliminary tests.

Over winter break, we plan to have more detailed conversations with Airpot engineers to figure out which products of theirs are best suited for the task at hand.